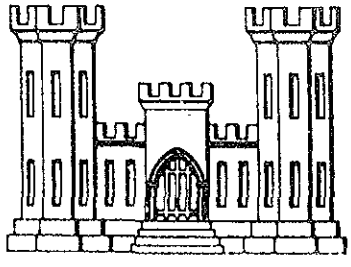
CONNECTICUT RIVER FLOOD CONTROL

WARE

LOCAL PROTECTION

WARE RIVER & MUDDY BROOK, MASSACHUSETTS

GENERAL DESIGN MEMORANDUM



Corps of Engineers, U.S. Army - Office of the Division Engineer

New England Division - Boston, Mass.

APRIL, 1957

CORPS OF ENGINEERS, U. S. ARMY
OFFICE OF THE DIVISION ENGINEER
NEW ENGLAND DIVISION
150 CAUSEWAY STREET
BOSTON 14, MASS.

ADDRESS REPLY TO:
DIVISION ENGINEER

REFER TO FILE NO.

NEDGW

10 April 1957

SUBJECT: Submission of Design Memorandum for Local Protection Project, Ware River, Connecticut River Basin, Ware, Massachusetts

TO: Chief of Engineers
Department of the Army
Washington 25, D. C.
ATTENTION: ENGWD

1. There are submitted herewith for review and approval ten (10) copies of the General Design Memorandum entitled "Local Protection Project, Ware River, Connecticut River Basin, Ware, Massachusetts." The location and general plan of recommended improvements are designated. Minor adjustments will be required as more complete information becomes available from final design investigations.

2. The Town of Ware by act of its town meeting and in accordance with State legislation has obligated itself to pay all costs in excess of the $400,000 statutory limitation up to a ceiling of $50,000. The town has also furnished satisfactory preliminary assurances that it will furnish all other requirements of local cooperation. It is requested that the Division Engineer be authorized to approve the formal assurances with the $50,000 limitation.

3. It is proposed to utilize the services of an Architect-Engineer for preparation of contract plans and specifications working directly under the supervision of the Division Engineer. The work does not involve great complexity of structures, difficulty in foundation conditions, or uniqueness in design. The plans and specifications will be prepared substantially in accordance with the Design Memorandum as approved and will be approved by the Division Engineer in accordance with Orders and Regulations. Copies of the plans and specifications will be forwarded to the Office, Chief of Engineers at the time of advertisement for the contract in August 1957. It is requested that approval be expedited in order that construction may be undertaken during the coming construction season.

4. Funds in the amount of $24,000 are requested for preparation of plans and specifications. By separate letter, after determination of exact unobligated balances, it is planned to request revocation of funds remaining from allotments for the Chicopee Falls and Norwalk projects, for which the estimated project cost has been found to exceed $400,000, and reallotment to the Ware River project.

FOR THE DIVISION ENGINEER:

Miles L. Wachendorf

MILES L. WACHENDORF
Lt. Colonel, Corps of Engineers
Executive Officer

Incl
Design Memo (cys 1-10 Incl)

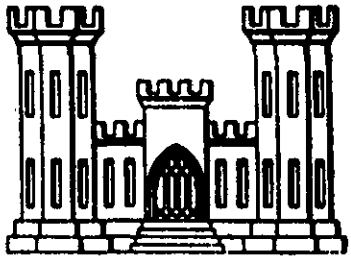
CONNECTICUT RIVER FLOOD CONTROL

WARE

LOCAL PROTECTION

WARE RIVER & MUDDY BROOK, MASSACHUSETTS

GENERAL DESIGN MEMORANDUM



Corps of Engineers, U.S. Army - Office of the Division Engineer

New England Division - Boston, Mass.

APRIL, 1957

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LOCAL PROTECTION PROJECT
WARE RIVER
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WARE, MASSACHUSETTS

GENERAL DESIGN MEMORANDUM

1. PERTINENT DATA

Physical Features

1. Location. - Ware River from the vicinity of the downstream end of the state dike to approximately one-half mile below Malbeouf Road Bridge, and on Muddy Brook near the town water pumping plant.

2.	Type of Improvement	Channel improvement and earth dikes.
3.	Length of Improvement	
	a. Channel Excavation	12,000 feet
	b. Water Pumping Plant Dike	950 feet
	c. St. William's Cemetery Dike	175 feet
4.	Hydrology	
	a. Maximum Flood of Record (Sept 1938)	
	Ware River at Gibbs Crossing Gaging Station	22,700 c.f.s.
5.	Channel Dimensions	
	a. Bottom width	90 feet
	b. Side slopes	1 vertical on 2 horizontal
6.	Water Pumping Plant Dike	
	a. Top width	10 feet
	b. Side slopes river side	1 vertical on $2\frac{1}{2}$ horizontal
	land side	1 vertical on 2 horizontal

7. St. William's Cemetery Dike

a. Top width	10 feet
b. Side slopes	1 vertical on 2 horizontal

Cost Estimates

1. First Costs

a. Federal	$400,000
b. Non-Federal	$ 85,000

2. Annual Costs

a. Federal	$ 14,000
b. Non-Federal	$ 5,000
c. Total	$ 19,000

CORPS OF ENGINEERS, U. S. ARMY
OFFICE OF THE DIVISION ENGINEER
NEW ENGLAND DIVISION
BOSTON 14, MASS.

LOCAL PROTECTION PROJECT
WARE RIVER
CONNECTICUT RIVER BASIN
WARE, MASSACHUSETTS

GENERAL DESIGN MEMORANDUM

10 April 1957

2. AUTHORITY

This design memorandum is submitted pursuant to authority contained in Section 205 of the Flood Control Act of 1948 as amended by Section 212 of the Flood Control Act of 1950 and Public Law 685, 84th Congress, 2nd Session. Further authority is contained in reply dated August 2, 1956 from the Chief of Engineers to a letter dated 18 July 1956 from the Division Engineer, New England Division, subject: "Local Protection Project - Ware River, Ware, Massachusetts."

3. SCOPE OF DESIGN MEMORANDUM

3.1 Scope. - This design memorandum reviews the flood control problem in Ware, Massachusetts, in the area downstream from the South Street Bridge and submits a definite project for improvement of the Ware River and construction of short earth dikes in Ware, Massachusetts.

3.2 Topographic Surveys. - A plane table survey of the flooded area in Ware on a scale of 1" = 100' with a contour interval of 5 feet, made in 1939, was field checked and supplemented by new valley sections along the Ware River and Muddy Brook.

3.3 Subsurface Explorations. - Explorations for the project consisted of a reconnaissance to study the general geology of the area, locate bedrock exposures and to determine as far as possible excavation properties of materials present. Additional explorations and borings will be made in the development of final plans.

3.4 Flood Damage Surveys. - Flood damage surveys were made after the floods of September 1938 and August 1955. The surveys consisted of the inspection of properties damaged by the flood and interviews with property owners and officials of the industries concerned, municipalities and the Commonwealth. The results of flood damage surveys are summarized in Section 12 of this design memorandum.

3.5 Conferences with Local Interests. - Close liaison has been maintained with state and town officials, local property owners and other interested parties. Plans for the protective works have been reviewed by representatives of the Town of Ware. Desires of the local interests are described in Section 15. All have expressed a strong desire for the immediate construction of flood protection works and in many instances during the course of the study have furnished valuable information.

4. PRIOR REPORTS

4.1 Survey Report. - Flood control improvements for Ware, Massachusetts have not been included in any published Survey Report.

4.2 Review Report. - An unpublished comprehensive report entitled "Connecticut River, Review of Reports on Flood Control" was prepared by the Providence District of the Corps of Engineers and submitted on 28 February 1940. Consideration was given to a system of earth dikes and concrete walls including 3 stop-log structures, 4 pumping stations and 5 gate structures for existing power canals. This proposal was found uneconomic at that time. Subsequently, the Commonwealth of Massachusetts and local interests constructed a dike, herein referred to as the State Dike, to provide protection against moderate floods in part of the town.

4.3 NENYIAC Report. - The comprehensive report entitled "The Resources of the New England-New York Region," prepared by the New England-New York Inter-Agency Committee, recommended that the State Dike in Ware be extended to high ground and that stop-log structures, pumping facilities and gate structures be installed.

5. DESCRIPTION OF AREA

5.1 Geography. - The Ware River drains an area of 221 square miles in central Massachusetts, excluding the basin of the Swift River, a major tributary which enters the Ware River 0.8 mile above its mouth. The basin has a maximum length of 33 miles and an average width of 8 miles. Originating in Barre, Massachusetts, it flows in a general south-westerly direction to Three Rivers in the Town of Palmer, Massachusetts, where it joins with the Quaboag River to form the Chicopee River, an important tributary of the Connecticut.

The Town of Ware is located 21 miles north-east of Springfield and 22 miles west of Worcester. Muddy Brook joins the Ware River from the north near the upstream limit of the project area. A map of the Chicopee River Basin is shown on Plate No. 1.

5.2 Topography. - The Ware River Basin is generally hilly and exhibits the surface characteristics and irregular drainage patterns typical of glaciated areas of southern New England. Hills are prominent and valleys are steep and narrow. Most of the tributary streams are oriented in a north-south direction and flow almost due southerly to where the pre-glacial valleys enter the Ware River. In the headwater areas in the vicinity of Princeton, Massachusetts, hills rise to elevations of 1,560 feet above mean sea level. In its course through the basin, the river has cut down to bed rock and has created rapids and falls at a number of places. The terrain in Ware is typical of the basin, with hills of moderate to sharp relief rising to elevations of about 1,100 feet m.s.l. In the $2\frac{1}{2}$ mile reach from South Street at Ware to the gaging station at Gibbs Crossing, the Ware River falls from an elevation of 397 to 380 feet, m.s.l. The flood plain in the upper portion of this reach is relatively wide and flat and in the lower portion downstream of Malbeouf Road Bridge is appreciably narrowed.

5.3 Geology. - Existing topography and the principal drainage pattern in the Ware River Valley near Ware are essentially determined by the schist and granitic bed rock surface and to some extend by glacial deposits. Sand and gravel deposits forming ridges and knolls occur in the valleys and the lower slopes of the hills. Rock outcrops and large boulders occur in the river bed near the Malbeouf Road Bridge and downstream near Stations 107+00 and 118+00. Upstream of Malbeouf Road the river flows through a wide flood plain with very little gradient. No ledge or boulders are evident in this reach.

5.4 Maps. - The Ware River area is shown on standard quadrangle sheets of the U. S. Geological Survey, scale 1:31680 and on Army Map topographic maps at a scale of 1:25,000.

6. CLIMATOLOGY

6.1 General. - The Ware River basin has a continental type climate, modified by the effects of the Atlantic Ocean. Variable weather conditions within the seasonal regimen are common. The basin lies in the path of the prevailing westerlies and is exposed to the cyclonic distrubances that cross the country from west or southwest toward the east or northeast. The area is subject also to storms that travel up the Atlantic Coast in the form of hurricanes of tropical origin or extratropical storms called "northeasters".

6.2 Temperature. - Because of the continental climatic control, the seasons are sharply contrasted and pronounced temperature changes are common. The extreme maximum temperatures in the 62-year record at Worcester (20 miles east of Ware and at a comparable elevation) range from 66°F. in February to 102°F. in July and the corresponding minimum temperatures from -24°F. in February to 41°F. in July.

6.3 Precipitation. - Average annual precipitation over the Ware River basin above Ware is about 45 inches, as estimated from data prepared by the U. S. Weather Bureau in 1955. On the average, precipitation is nearly uniformly distributed throughout the year, but there is considerable year to year seasonal variation. Table 1 summarizes the 62-year temperature record and the 113-year precipitation record, by months, for Worcester, Massachusetts.

TABLE 1

MONTHLY TEMPERATURE AND PRECIPITATION

Worcester, Massachusetts

	Temperature, °F.			Precipitation, Inches		
		Extremes				
Month	Mean	Maximum	Minimum	Mean	Maximum	Minimum
January	25.5	69	-17	3.55	9.03	0.70
February	25.4	66	-24	3.19	8.09	0.67
March	35.0	84	- 6	3.87	11.13	0.04
April	45.7	91	8	3.61	8.87	0.51
May	57.2	92	27	3.77	7.38	0.88
June	66.0	96	33	3.39	8.31	0.66
July	71.0	102	41	3.61	11.41	0.62
August	68.9	99	35	4.06	18.58	0.35
September	62.0	100	26	3.53	10.82	0.20
October	51.8	89	13	3.62	10.79	0.36
November	40.1	81	3	3.77	9.82	0.66
December	28.5	67	-17	3.50	7.77	0.78
Annual	48.1	102	-24	43.47	61.71	27.92

6.4 Snow. - During the winter and spring months snow is an important hydrologic factor. Melting snow alone seldom produces damaging floods, but, when combined with heavy rainfall, snow-melt may constitute the difference between damaging and non-damaging high water. About one-half of the winter precipitation on the Ware River basin is in the form of snow. Mean annual snowfall at Hubbardston, in the Ware River basin above Ware, is approximately 60 inches. In the upper portion of the basin, the water equivalent of the snow pack often reaches 4 to 6 inches.

6.5. Storms. - The New England region experiences a large number of extratropical cyclones each year because the paths of these storms tend to converge on the northeastern United States. In summer these migratory storms are usually weaker and the paths somewhat further north. Much of the summer precipitation is from convective showers and thunderstorms. Tropical hurricanes constitute an infrequent but very important potential for flood-producing precipitation, particularly from August to October. Although the more intense short-period precipitation is usually experienced in the summer and fall months, flood-producing precipitation may occur in any season of the year.

7. RUNOFF

7.1 Discharge Records. - Stream flow in the Ware River is measured at three U. S. Geological Survey gaging stations. Data on these stations are summarized below:

STREAM GAGING STATIONS

WARE RIVER

Stream	Station	Drainage Area (Sq. Mi.)	Period of Record
Ware River	Barre	55.0	1946-present
Ware River	Coldbrook	96.8	1928-present
Ware River	Gibbs Crossing	199	1912-present

Locations of these stations are shown on Plate No. 1. Records from the two downstream stations are generally good and from the station near Barre generally excellent, as classified by the Geological Survey. There are no flow records for Muddy Brook.

7.2 Runoff. - Flow data applicable to the project area is determined from the Gibbs Crossing U.S.G.S. gaging station records. Table 2 gives the monthly and annual runoff record for the Gibbs Crossing gaging station, adjusted for diversions at Coldbrook.

TABLE 2

MONTHLY RUNOFF, C.F.S.

Ware River at Gibbs Crossing

Month	Mean	Maximum	Minimum
January	338	765	66
February	320	812	93
March	678	1945	226
April	717	1712	240
May	419	754	156
June	263	604	65
July	171	715	56
August	124	1036	29
September	161	1710	14
October	131	488	29
November	236	732	34
December	305	737	59
Annual	322	1945	14

8. FLOODS OF RECORD

8.1 Flood Causes. - Flooding in Ware is usually caused by heavy rainfall or heavy rainfall combined with melting snow. Serious floods can be expected to occur during any season of the year. Runoff is rapid due to generally hilly topography and thin soil cover which is not conducive to infiltration of heavy rainfall for any appreciable length of time.

8.2 Historic Floods. - Limited information concerning major floods in the Ware River basin dates back to the late 19th century. Except for floods which occurred in the past 45 years, information is scant and general. Major floods occurred in October 1869 and February 1900 but no data on peak discharges are available.

8.3 Major Floods of Record. - Reliable records of flood stages and discharges of the Ware River at Gibbs Crossing have been kept since 1912. Five major floods have occurred during the period of record, three of which caused heavy damages in the project area. A summary of these five floods is given in Table 3.

TABLE 3

FLOODS OF RECORD

Ware River at Gibbs Crossing
(Drainage Area 199 sq. mi.)

Date	Peak Discharge (c.f.s.)
21 September 1938	22,700
19 August 1955	12,200
19 March 1936	11,200
12 March 1936	5,200
25 June 1944	4,930

The September 1938 and August 1955 floods were caused by rainfall associated with tropical hurricanes. A combination of rainfall and snowmelt caused the two flood peaks of March 1936. Plate 5 shows storm isohyetal maps, mass precipitation curves, and flood hydrographs for the 1938 and 1955 floods. Modified hydrographs reflecting the downstream effect of Barre Falls Reservoir also are shown. As indicated, Barre Falls Reservoir would have effected a substantial reduction of the 1938 flood, but, because of a difference in storm center location and rainfall distribution, would have reduced the 1955 flood only slightly.

9. FLOOD FREQUENCY

9.1 The frequency, or percent chance of occurence in any one year, of peak discharges on the Ware River was determined from records of the U. S. Geological Survey gaging station at Gibbs Crossing in accordance with procedures described in Civil Works Engineer Bulletins 51-1 and 51-14. On the basis of a regional study for all of New England, a skew factor of 0.8 was applied to the Ware River flood distribution. The natural and modified frequency curves are shown on Plate 5.

10. STANDARD PROJECT FLOOD

10.1 General. - A standard project flood for the Chicopee River (to be used for all projects being considered in the Chicopee River Basin) was developed in accordance with Civil Works Engineer Bulletin No. 52-8. Ware River components of the standard project flood were computed for Barre Falls dam site, the town of Ware, and Malbeouf Road Bridge. Modified standard project flood components indicating the effect of Barre Falls Reservoir were computed for the two downstream locations.

10.2 Standard Project Storm. - Following criteria outlined in Civil Works Engineer Bulletin No. 52-8, a standard project storm isohyetal pattern was developed for the entire Chicopee River basin. Total storm depths averaged over the areas above Barre Falls dam site and Malbeouf Road Bridge amount to 11.1 and 12.0 inches, respectively. The precipitation was rearranged into a storm pattern, and losses of 0.40 inch per 6-hour period were taken for infiltration, surface detention, and other factors. Rates of precipitation, losses, and precipitation excesses, by 6-hour increments, are listed in Table 4.

TABLE 4

STANDARD PROJECT STORM
(in inches)

	Area Above Barre Falls Damsite			Area Above Malbeouf Road Bridge		
Time	Precip.	Losses	Precip. Excess	Precip.	Losses	Precip. Excess
0	0	0	0	0	0	0
6	0.51	0.40	0.11	0.56	0.40	0.16
12	0.81	0.40	0.41	0.88	0.40	0.48
18	6.87	0.40	6.47	7.40	0.40	7.00
24	0.59	0.40	0.19	0.65	0.40	0.25
30	0.45	0.40	0.05	0.45	0.40	0.05
36	0.40	0.40	0	0.40	0.40	0

10.3 Unit Hydrographs. - Six-hour unit hydrographs were derived from analyses of floods of record. The adopted hydrograph for Barre Falls dam site has a peak discharge of 2,300 second-feet, or 42 second-feet per square mile. At Malbeouf Road Bridge the peak discharge is 6,000 second-feet, or 31 second-feet per square mile.

10.4 Standard Project Flood. - Ware River components of the Chicopee River standard project flood were derived by applying the precipitation excesses to the applicable unit hydrographs and adding base flow. Table 5 lists the natural and modified standard project flood peak discharges.

TABLE 5

PEAK DISCHARGES - STANDARD PROJECT FLOOD

Location	Drainage Area (Sq. Mi.)	Peak Discharge (c.f.s.)
Natural at Barre Falls Dam	55	15,300
Natural at Ware	170	41,000
Modified at Ware by Barre Falls Dam	115	34,000
Natural at Malbeouf Road Bridge	191	45,000
Modified at Malbeouf Road Bridge by Barre Falls Dam	136	38,000

11. PROJECT DESIGN FLOOD

Consideration was given to the design of the project for the 33,000 cubic feet per second peak discharge of the standard project flood as modified by Barre Falls Dam. Provision of adequate channel capacity for this flood would result in costs materially in excess of the statutory limitation for Public Law 685 projects and preliminary estimates indicated that the benefits would be insufficient to justify the cost of such a channel. In consequence, a project design flood equal to the flood of record without modification by the Barre Falls project was adopted. The project design flood has natural peak discharges of 20,000 and 22,000 second feet above and below Muddy Brook respectively. Table 6 lists natural and modified project design flood peak discharges.

TABLE 6

PEAK DISCHARGES - PROJECT DESIGN FLOOD
(September 1938)

Location	Drainage Area (Sq. Mi.)	Peak Discharge (c.f.s.)
Natural at Barre Falls Dam	55	8,000
Natural at Ware	170	20,000

TABLE 6 (cont'd)

PEAK DISCHARGES - PROJECT DESIGN FLOOD
(September 1938)

Location	Drainage Area (Sq. Mi.)	Peak Discharges (c.f.s.)
Modified at Ware by Barre Falls Dam	115	14,400
Natural at Malbeouf Road Bridge	191	22,000
Modified at Malbeouf Road Bridge by Barre Falls Dam	136	16,400

12. FLOOD LOSSES

12.1 General. - The flood of September 1938, the record flood of the Ware River, caused a total loss of $1,720,000 in the Town of Ware, Massachusetts. About 40 percent of this loss was sustained by six manufacturing concerns. Residential and commercial properties were also hard hit, and some 30 small produce and dairy farms in the area suffered damages to crop land and buildings. About 150 houses and nearly 50 commercial establishments lying within the project area were affected. Both the East and South Street highway bridges were washed out, and three railroad bridges, including extensive sections of track, were destroyed. The flood of August 1955 caused a total loss of $460,000. Flooding near the mouth of Muddy Brook in 1955, which reached a stage about 6 feet below the 1938 crest, caused $130,000 in residential and commercial damages and the water supply to the town was disrupted.

A recurrence of the stages caused by the flood of 1938, under economic conditions of 1956, would cause losses of over $3,900,000 in Ware, including damages to several industrial concerns which have located within the flood area since 1938. Of this total approximately $3,600,000 in damages would occur in the local protection area downstream of South Street.

12.2 Annual Losses. - Estimated recurring flood losses have been converted to annual losses to provide a basis for comparing annual benefits to annual costs. Average annual losses have been derived in accordance with standard Corps of Engineers practice of utilizing stage-damage, stage-discharge, and discharge-frequency relationships.

Annual losses under natural conditions in the local protection area between South Street and Malbeouf Road Bridge amount to $83,600. Flood-stage reductions effected by Barre Falls Dam and Reservoir would reduce this annual loss to $51,800. Typical curves used in the computation of annual losses are shown on Plate No. 6.

13. EXISTING CORPS OF ENGINEERS FLOOD CONTROL PROJECTS

13.1 Barre Falls Reservoir. - The Flood Control Act of 1938 authorized the Barre Falls flood control reservoir in the Ware River basin. The Barre Falls Damsite is on the Ware River in the Town of Barre, Massachusetts, approximately 21 miles upstream from the center of Ware. The project provides for 24,300 acre-feet of flood control storage, which is equivalent to 8.3 inches of runoff from its drainage area of 55 square miles. (Previously published drainage area of 57 square miles has been revised as a result of completion of revised mapping by the U.S.G.S.) This drainage area represents 29% of the drainage area of 191 square miles at the Malbeouf Road Bridge. The reservoir, currently under construction, would effect a 2-foot stage reduction in the standard project flood at Ware. The total estimated cost of the Barre Falls project is $2,060,000 (1956 price level). The authorized Barre Falls Reservoir is the only Federal flood control project in the Ware River basin.

14. IMPROVEMENTS BY OTHER FEDERAL AND NON-FEDERAL AGENCIES

14.1 State Dike. - The Commonwealth of Massachusetts and local interests have constructed an earth dike and flood wall on the right bank from South Street downstream to West Street in the vicinity of St. William's Cemetery. The project has not been fully completed. Pumps with electric motors to provide for storm water discharge were purchased by the town and are in storage. They were not installed in view of the fact that electric power distribution facilities sometimes fail during floods. Under flood conditions water ponds in low land at the dike. In addition, the swale behind St. William's Cemetery has not been closed and flood water can enter the protected area through this swale.

15. IMPROVEMENTS DESIRED

An informal meeting was held at Ware, Massachusetts, on 14 September 1956. Approximately 30 persons attended, including representatives of the Board of Selectmen, Town Engineer and Water Superintendent, other local officials, manufacturers, businessmen, and representatives of the Ware Flood Control Committee. All expressed strong support for the immediate construction of improvements and urged that the river be dredged downstream of the town. At a subsequent meeting on 5 March 1957 with approximately the same representation, the local interests concurred with the project, as described herein.

16. FLOOD PROBLEMS AND SOLUTIONS CONSIDERED

16.1 Flood Problem. - The Ware River basin is susceptible to floods caused by heavy rains or a combination of heavy rains and

melting snow. Runoff is rapid owing to generally hilly topography and a thin soil cover which is not conducive to infiltration of heavy rainfall for any appreciable time. Developed areas of Ware consisting of industrial and commercial sites with many residential developments are located in the flood plain. A recurrence of the September 1938 flood in Ware without flood protection would cause an estimated loss of $3,900,000.

16.2 Solutions Considered. - Several methods of protecting lower Ware from damaging floods by means of dikes were considered. A preliminary analysis indicated that a general channel improvement on the Ware River or reservoirs on the tributary streams might provide a solution. Several combinations of the general channel improvement with dikes and floodwalls were considered and the best plan of protection is described in Section 17.

16.3 Reservoirs. - The analyses of possible reservoirs made for previous reports indicated that upstream reservoirs would not be justified at that time. In the event that additional reservoirs are developed as a result of the authorized review of prior reports on the Connecticut River Basin, such reservoirs would serve to increase the degree of protection provided by local works.

17. DESCRIPTION OF PROPOSED IMPROVEMENTS

17.1 Channel. - The proposed channel, as shown on Plate No. 2, would extend about 12,000 feet, have a minimum bottom width of 90 feet, a slope of 1 foot per 1,000 feet, and the sides of the channel would be excavated to a 1 on 2 slope. It includes removal of a pronounced downstream hydraulic constriction resulting from an outcropping rock ledge in the vicinity of the Malbeouf Road Bridge. The river bottom is higher here than at any location within 1½ miles upstream. The horizontal control created by the bridge also tends to increase upstream water depths but is of lesser hydraulic importance than the elevated river bed. During flood periods this control causes extensive overbank ponding of water in the area upstream from the bridge which at times extends into the developed portion of the Town of Ware. Removal of this constriction is a basic element of the recommended plan of improvement. Studies were made for several combinations of bottom grades, depths and sizes of channel to determine the most effective and economical combination. The largest amount of excavation will be in the vicinity of Malbeouf Road Bridge. Above the mouth of Muddy Brook the existing channel is larger than below, and very little excavation would be required. The Ware River channel excavation also includes partial removal of the hydraulic control where an old railroad fill crosses the flood plain near Station 36+00 and confines the entire flow to the stream channel. Approximately 100 feet of the fill will be removed to the elevation of the natural banks to reduce the

constriction and eliminate the hydraulic contraction where the overbank flow enters the main stream. For the final plans subsurface investigations will be made in the vicinity of Malbeouf Road to determine the possibility of an alternative channel alignment and elsewhere to determine the character of materials to be excavated.

17.2 Dikes. - Materials excavated in the channel would be utilized to construct the dikes which would provide complete protection in two critical areas. As shown on Plate No. 3, the Water Pumping Plant Dike would have a top width of ten feet with a 1 on 2 slope on the land side and a 1 on $2\frac{1}{2}$ slope on the brook side. The smaller St. William's Cemetery Dike shown on Plate 4 would have a top width of 10 feet with side slopes of 1 on 2. This dike would prevent overflow through a low swale northwest of St. William's Cemetery into the area protected by the existing works. The top of the dikes at elevation 415 are $2\frac{1}{2}$ feet above the observed 1938 highwater mark and would have a minimum freeboard of 3 feet above the project design flood high-water level. Excess material would be used to fill low areas. The dike slopes would be topsoiled, seeded and mulched for surface protection. In the past, flooding of the areas behind the dikes has been caused by both the flood peak of Muddy Brook and backwater from the main Ware River flood crest. Usually the Muddy River peak precedes the Ware River peak by several hours. Flooding along lower Muddy Brook through backwater of the Ware River will be substantially reduced by the recommended channel improvement, and flooding due to Muddy Brook itself will be reduced by replacement by local interests of two bridges over lower Muddy Brook as discussed in paragraph 17.3. The replacement of these two bridges will increase the degree of protection for the project.

17.3 Bridges. - The existing Malbeouf Road Bridge forms a constriction in the Ware River. Local interests would either replace it with a bridge of sufficient span at a higher elevation or abandon it to permit removal of the constriction. The bridge is not used extensively and its permanent abandonment would not cause severe hardship. The two bridges over Muddy Brook at West Street and West Main Street have inadequate waterway openings which are further reduced by several suspended utility pipes. During past floods these bridges were constrictions, forcing water over the roads approaching the bridges. These bridges will be replaced by the Commonwealth of Massachusetts to provide adequate waterway openings.

17.4 Drainage

17.4.1 Water Pumping Plant Dike. - Modification of drain pipes under the water pumping plant dike and now terminating at the brook will be required. A 12-inch pipe through the dike with a flap gate and manually operated sluice gate will be provided

where ground elevations behind the dike are lower than the computed high water elevations in the brook at the pipe outlets. Local surface runoff will accumulate in low areas behind the dike under extreme conditions and portable pumps provided by the town will be used to discharge the water over the dike.

17.4.2 St. William's Cemetery Dike. - There are no special provisions provided for drainage around the St. William's Cemetery Dike. It is recognized that local surface runoff may accumulate briefly in low areas under extreme conditions and that the excess will drain to the West Street sewers.

17.4.3 Existing State Dike. - Most of the drainage at the existing State Dike is conducted to a reinforced concrete drain sump constructed as an integral part of the flood wall section of the State Dike and designed to serve as a pumping station foundation. As shown on Plate No. 4, a 12-inch storm sewer passes under the dike without provision for pumping. This pipe would be plugged and the drainage diverted to the present intercepting system.

17.4.4 Pumping. - To fully complete the State Dike, installation of pumps would be required to eliminate ponding in low areas during floods. Two pumps each with 12-inch suction and 10-inch discharge, rated at 2200 G.P.M. at 18-foot head and 575 R.P.M. with all necessary valves and piping, were purchased by the town. These pumps provide sufficient capacity to discharge approximately one-half inch of run-off per hour from the drainage area behind the dike. This will eliminate ponding behind the dike except under most extreme conditions. The pumping installation at the State Dike would be completed using gasoline or diesel engines under the present project. This will be a separate contract to be initiated when the final contract costs are established and available funds become known. In the event that costs are higher than estimated and the installation can not be included in the Federal portion of the project, it will be accomplished as a location portion (see Section 25).

17.5 Hydraulic Design

17.5.1 Water Surface Elevations. - The upper line on the profile on Plate 2, showing water levels observed during the September 1938 flood, may be compared directly with the lower water surface profile showing computed elevations for the improved channel. The reductions for the 1938 flood would have been 10 feet at Malbeouf Road Bridge and 4.5 feet at the mouth of Muddy Brook and the corresponding reduction at the South Street Bridge in Ware would have been 4 feet. This results in a freeboard of approximately 5 feet on the State Dike for the project design flood. Also shown on Plate 2 are profiles for the August 1955 flood as observed and as computed for the improved

channel. The rating curves on Plate 2 show natural and modified water stages for all discharges up to 30,000 second-feet for two locations, Malbeouf Road Bridge and the mouth of Muddy Brook. At the downstream limit of the project the depth-discharge relationship was computed for an average section and slope from that point to the U.S.G.S. gaging station at Gibbs Crossing, 0.9 miles below Malbeouf Road Bridge. The water surface profiles for the improved channel were developed by backwater computations, using a roughness coefficient of 0.030 and assuming that the bridge at Malbeouf Road will be relocated with an adequate waterway opening and a lowered channel bottom. A roughness coefficient of 0.035 was used for reaches where little or no improvement is required.

17.5.2 Velocities. - Computed average velocities for major floods in the Ware River, both above and below Muddy Brook, are less than 10 feet per second. Since the 10 foot per second velocity would prevail for only a short period of time during the peak of the flood, it is not considered necessary to provide special bank protection against high-velocity flows. The maximum computed increase for the sharpest river curve is less than a foot and superelevation is considered unnecessary.

17.6 Sources of Construction Materials

17.6.1 General. - Materials for construction of the dikes would be selected from sand and gravel excavated in connection with the widening and deepening of the channel. Impervious material may be obtained from the channel or if necessary from deposits located within five miles of the project. A disposal area has been designated by local interests on the right bank of Muddy Brook just upstream from West Main Street. Additional disposal areas will be located and shown on the final plans.

17.6.2 Concrete Aggregates. - Approximately 16 cubic yards of concrete will be required for the project. In view of the small quantity of concrete involved, aggregate investigations have been confined to established commercial sources. The four commercial sources within a radius of 15 miles of the project site were recently investigated and tested in connection with other projects.

Selection of sources for testing was based on plant facilities and characteristics of materials as determined by visual examination. All of the natural sand and gravel sources investigated are developed in Pleistocene glacial outwash deposits and exhibit lithological similarity.

Estimated costs of aggregates from the four sources tested, based on quoted prices and Massachusetts Department of Public Utilities minimum trucking rates which are currently 25 cents per ton for the first mile and 5 cents per ton for each additional mile are indicated in the following table:

TABLE 8 - CONCRETE AGGREGATE INFORMATION

Commercial Source	Haul Distance	Gravel Plant Price	Gravel Delivered Price	Conc. Sand Plant Price	Conc. Sand Del'd Price
North Wilbraham Sand and Gravel Co. North Wilbraham Massachusetts	16	$1.50/ton	$2.50/ton	$ .85/ton	$1.85/ton
D. D. Ruxton Co. Ludlow, Massachusetts	14	$1.35/ton to $1.70/ton	$2.43/ton	$ .90/ton	$1.75/ton
A. Giard & Sons, Inc. Ware, Massachusetts	5	$1.85/ton to $2.25/ton	$2.50/ton	$1.10/ton	$1.55/ton
R. T. Curtin Sand & Gravel Corp. Barre, Massachusetts	17	$1.70/ton	$2.75/ton	$ .90/ton	$1.95/ton

Based on the above data presented, it is considered that aggregate from any of the four sources tested are acceptable for use in concrete for the project, and it is recommended that all four sand and gravel sources be approved for fine and coarse aggregate.

18. MULTIPLE-PURPOSE FEATURES

The Ware Local Protection Project is designed solely for flood protection and contains no multiple-purpose features.

19. RECREATIONAL DEVELOPMENT

The components of the project are unsuitable for recreational development.

20. ESTIMATES OF FIRST COST AND ANNUAL CHARGES

The total estimated first cost of the Ware Local Protection Project is $485,000, with annual charges estimated at $19,000. First costs to the United States and to local interests are estimated at $400,000 and $85,000 respectively. Federal annual charges would amount to $14,000 and non-Federal to $5,000.

Estimates have been prepared on the basis that local interests would bear the entire cost of relocations, furnish all lands and rights-of-way necessary for construction and operation of the project, including disposal areas for excavated materials not used in the dikes, and, in addition, make a cash contribution of part of the construction cost in the event that the Federal cost were to exceed the statutory limitation of $400,000. Local interests would also be required to maintain and operate the project after completion.

Unit prices used in estimating costs are based on average bid prices for similar work in the same general region. The adopted unit prices are adjusted to the 1957 price level and include minor items of work which do not appear in the cost estimates. Annual charges are based on an annual interest rate of 2.5 percent, with amortization of the project cost distributed over a 50-year period. A summary of first costs and annual charges is given in Table 8, starting on page 20.

21. ANNUAL BENEFITS

Average annual benefits have been derived by damage frequency analysis based upon current flood damage and hydrologic data. Benefits to local protection, including channel improvement and dikes, represent the difference between average annual losses remaining in the project area after Barre Falls reduction and losses remaining after local protection. Annual benefits attributable to local protection from reduction of flood damages amount to $35,900. A breakdown of annual losses and benefits within the project protection area between South Street and Two Mile Bridge follows:

Local Protection	Annual Losses Under Natural Conditions	Annual Losses After Barre Falls Reduction	Annual Benefit to Local Protection
Inside Dike Area	$ 22,900	$ 14,600	$ 10,900
Outside Dike Area	60,700	37,200	25,000
	$ 83,600	$ 51,800	$ 35,900

22. COMPARISON OF BENEFITS AND COSTS

Average annual benefits for the Ware Local Protection Project are estimated at $35,900 and average annual costs are estimated at $19,000. The resulting ratio of benefits to costs is 1.9 to 1.0.

TABLE 8

COST ESTIMATE

First Costs (1957 Base)

FEDERAL

	Unit	Quantity	Units	Estimated Amount
Channel				
Clearing of Site		L.S.		$ 5,000
Excavation Rock	cu. yd.	25,000	6.25	156,250
Excavation Earth	cu. yd.	100,000	1.00	100,000
Remove Bridge and Abutments		L.S.		5,000
Dike				
Embankment	cu. yd.	25,000	.30	7,500
Impervious fill	cu. yd.	8,000	.80	6,400
Top Soil	cu. yd.	2,500	2.00	5,000
Seeding and Mulching	Acres	3	800.00	2,400
Stripping	cu. yd.	450	1.00	450
Other				
Drainage		L.S.		7,500
				$ 295,000
Contingencies @ 15%				44,800
Total Construction Cost				$ 339,800
Engineering and Design 9%				30,600
				$ 370,400
Supervision and Administration 8%				29,600
TOTAL ESTIMATED FEDERAL FIRST COST				$ 400,000

TABLE 8 (cont'd)

COST ESTIMATE

First Costs (1957 Base)

NON-FEDERAL	
New Bridge	$ 70,000
Land Costs	10,000
Relocation of Drains	5,000
TOTAL ESTIMATED NON-FEDERAL FIRST COST	$ 85,000
ANNUAL CHARGES	
Federal	
Interest (2.5% on $400,000)	$ 10,000
Amortization (1.026% on $400,000)	4,000
	$ 14,000
Non-Federal	
Interest (2.5% on $85,000)	$ 2,125
Amortization (1.026% on $85,000)	875
Maintenance	1,500
Loss in Taxes	500
	$ 5,000
TOTAL ANNUAL CHARGES	$ 19,000

23. SCHEDULES FOR DESIGN AND CONSTRUCTION

23.1 Design. - It is estimated that the preparation of contract plans and specifications for the project will require 2½ months. The estimated cost of plans and specifications is $24,000.

23.2 Construction. - Construction of the project would be accomplished in one construction season of five months' duration under a single contract proposed to be awarded in August 1957. All funds for the project should be available for obligation prior to award of the contract to permit completion of this urgently needed protection in the current construction season. Expenditures are estimated as follows:

Fiscal Year 1957	
Allotments to date (Design Memorandum)	$ 6,000
Planning	24,000
Construction	0
Total F.Y. Expenditures	$30,000
Fiscal Year 1958	
Construction	$370,000
Total	$400,000

24. OPERATION AND MAINTENANCE

Maintenance of the project and operation of the drainage control gate-valve will be the responsibility of local interests (see paragraph 4). Periodic inspections will be made to assure that adequate maintenance is performed in accordance with regulations prescribed by the Secretary of the Army. It is estimated that maintenance of the project will cost local interests $1,000 annually.

25. LOCAL COOPERATION

In accordance with Section 3 of the Flood Control Act of 1936, local interests would be required to provide without cost to the United States all lands, easements, and rights-of-way necessary for the construction and operation of the project; hold and save the United States free from damages due to construction works; and maintain and operate all the works after completion in accordance with regulations prescribed by the Secretary of the Army. The responsibility for furnishing disposal areas

for excavated materials not used in the dikes and for the relocation or modification of highways and utilities would rest with local interests under the requirements of lands, easements, and rights-of-way.

Local interests would also be required to furnish the added assurance that they would contribute to the United States all necessary funds over and above the Federal cost limitation of $400,000 if it is later found that the total construction cost would exceed that amount. This would include the installation of pumping facilities as a local cost in the event that it were not possible to include it in the Federal portion of the project.

There is an intense desire for flood protection in Ware. Town officials have indicated a willingness to fulfill the conditions of local cooperation. The town appropriated the sum of $50,000 at its annual town meeting to be set aside in a special fund to be used only if the project cost should exceed the sum of $400,000. Letters from the town authorities which constitute preliminary assurances are included herein as inclosures.

The selectmen have informally advised this office that the town cannot under Massachusetts law obligate itself to pay an indeterminate amount and in consequence, proposed the appropriation of $50,000. Any further appropriation would have increased the tax levy to be made this year. This appropriation is considered adequate assurance that the Federal cost will not exceed the statutory limitation of $400,000. The selectmen have also informally agreed to call a special town meeting to consider an additional appropriation for completion of the project should this be necessary.

26. COORDINATION WITH OTHER AGENCIES

Plans for the protective works in the Lower Ware area have been furnished for review by representatives of the Commonwealth of Massachusetts, the Town of Ware and the Fish and Wildlife Service. The project has no effect on Federal or State highways, recreation, pollution abatement or other collateral purposes.

27. CONCLUSIONS

It is concluded that the Ware River produces major flood damages in Ware, Massachusetts in the area downstream from the South Street bridge. The Lower Ware area faces the continuing threat of heavy damages in the future, and protection can be provided most suitably by construction of the Ware Local Protection Project at a total estimated first cost of $485,000. This plan would afford a high degree of protection and is economically justified. The ratio of annual benefits to annual costs is 1.9 to 1.0. The frequency of major floods and the existing concentration of industrial, commercial, and residential developments make immediate construction of the project imperative.

28. RECOMMENDATION

It is recommended that the project submitted in this report be authorized by the Chief of Engineers under the provisions of the Flood Control Act of 1948, as amended, and that additional funds in the amount of $24,000 for planning be allotted therefor.

TOWN OF WARE

MASSACHUSETTS

OFFICE OF
THE SELECTMEN

February 27, 1957

Corps of Engineers,
U. S. Army,
Office of Division Engineer,
New England Division,
150 Causway Street,
Boston 14, Mass.

Gentlemen:

Re: NEDGW

In accordance with standard procedures in such matters, this letter will confirm our authority to furnish lands and rights of way in connection with the proposed subject project.

We have contacted the Hampshire County Commissioners and have been advised that temporary abandonment of Malboeuf Road Bridge will probably be a local matter.

A proposal will be made to the voters of Ware at the Annual Town Meeting on March 11, 1957, that authorization be granted for the assumption of all costs of the project exceeding the sum of $400,000.00, by the Selectmen on behalf of the town.

Yours very truly,

Selectmen
of
Ware

TOWN OF WARE

MASSACHUSETTS

OFFICE OF
THE SELECTMEN

March 12, 1957

Corps of Engineers, U. S. Army,
Office of the Division Engineer,
New England Division,
150 Causeway Street,
Boston 14, Mass.

Re: NEDGW

Gentlemen:

Enclosed herewith is a certification of action taken by the Town of Ware at the Annual Town Meeting on March 11, 1957.

It reflects the appropriation of $50,000.00 for use in connection with the subject project, should said project exceed the cost of $400,000.00.

Yours very truly,

Roland W. Gravel,
Chairman.

TOWN OF WARE

MASSACHUSETTS

March 12, 1957

OFFICE OF
THE SELECTMEN

To:
Corps of Engineers, U.S.Army,
Office of the Division Engineer,
New England Division,
150 Causeway Street,
Boston 14, Mass.

Re: NEDGW

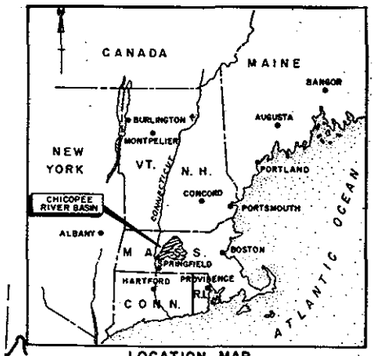
This is to certify that by action of the voters at the Annual Town Meeting held in Ware, Massachusetts on March 11th, 1957, the sum of fifty thousand ($50,000.00) dollars was transferred from Available Funds to an account titled "Ware River Dredging Fund", said sum to be used only if the proposed dredging and diking program under the subject symbol should exceed the cost of $400,000.00.

Selectmen
of
Ware

Attest:
Peter J. Rzeznikiewicz,
Town Clerk-Treasurer.

CORPS OF ENGINEERS

U.S. ARMY



LOCATION MAP

SCALE IN MILES

40 0 40 80

CHANNEL IMPROVEMENT

DIKES

WENDELL

ORANGE

SHUTESBURY

NEW SALEM

PELHAM

BELCHERTOWN

PHILLIPSTON

PETERSHAM

HUBBARDSTON

WESTMINSTER

HARDWICK

BARRE

CHICOPEE

EAST SPRINGFIELD

SPRINGFIELD

LUDLOW

WARE

WILBRAHAM

NEW BRAINTREE

OAKHAM

PRINCETON

WEST BROOKFIELD

RUTLAND

PALMER

MONSON

WARREN

NORTH BROOKFIELD

SPENCER

BRIMFIELD

BROOKFIELD

EAST BROOKFIELD

PAXTON

LEICESTER

WALES

STURBRIDGE

EAST BRIMFIELD

SCALE IN MILES

0 1 0

REVISION	DATE	DESCRIPTION	BY

CORPS OF ENGINEERS, U. S. ARMY
OFFICE OF THE DIVISION ENGINEER
NEW ENGLAND DIVISION
BOSTON, MASS.

DR. BY	TR. BY	CK. BY
S.F.C.	S.F.C.	G.E.B.

PROJECT ENGINEER

SUBMITTED BY
CHIEF, ENGINEERING DIV.

APPROVED
LT. COL., C.E. ASST. DIVISION ENGINEER

CONNECTICUT RIVER FLOOD CONTROL
CHICOPEE RIVER BASIN
WATERSHED MAP
CHICOPEE RIVER, MASSACHUSETTS

DATE APRIL 1957

SCALE: AS SHOWN

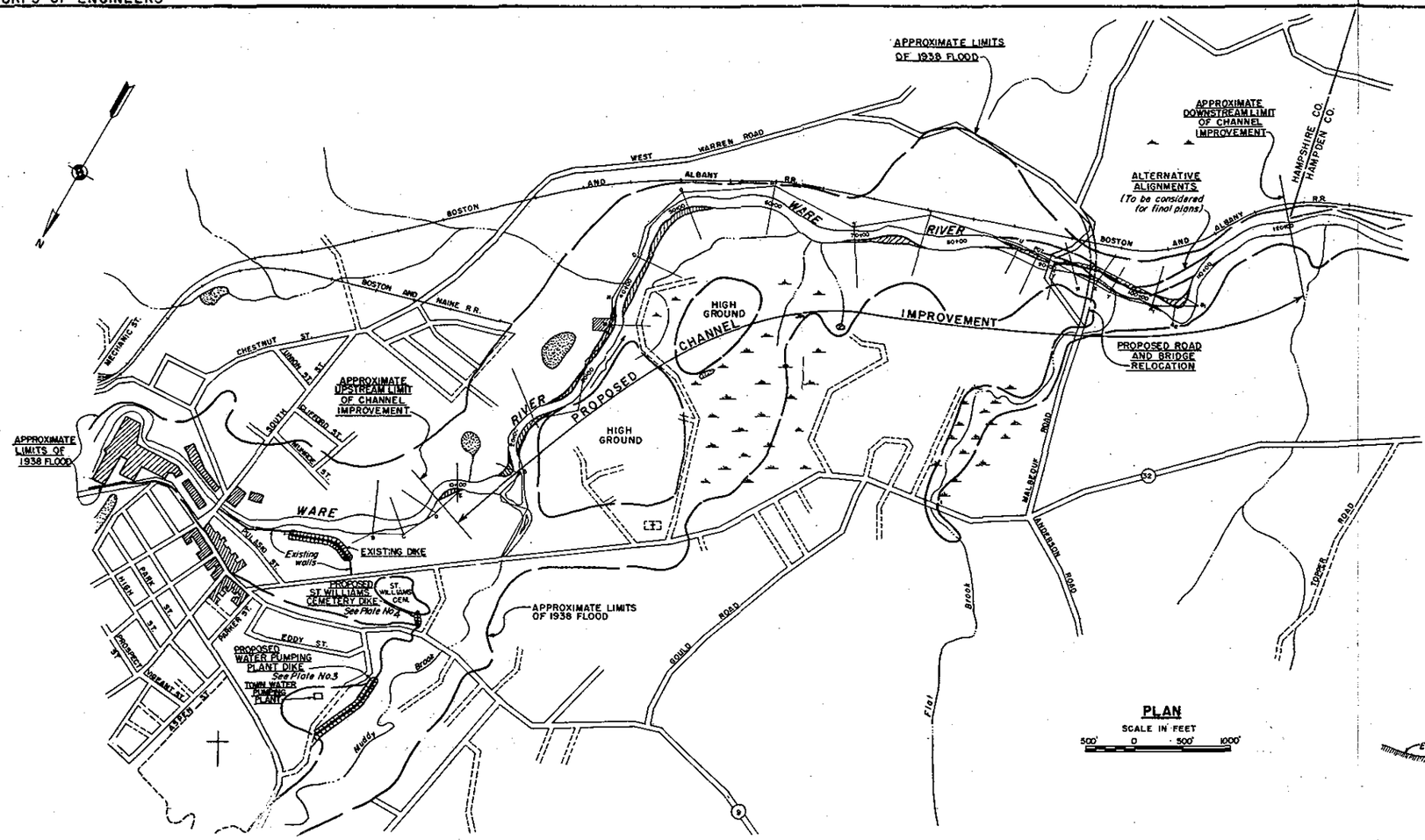
DRAWING NUMBER
CT-1-4436

SHEET 1 OF 1

PLATE NO. 1

CORPS OF ENGINEERS

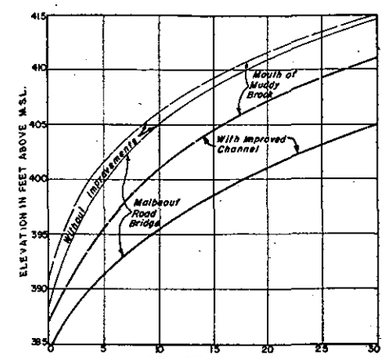
U.S. ARMY



PLAN

SCALE IN FEET

500' 0 500' 1000'



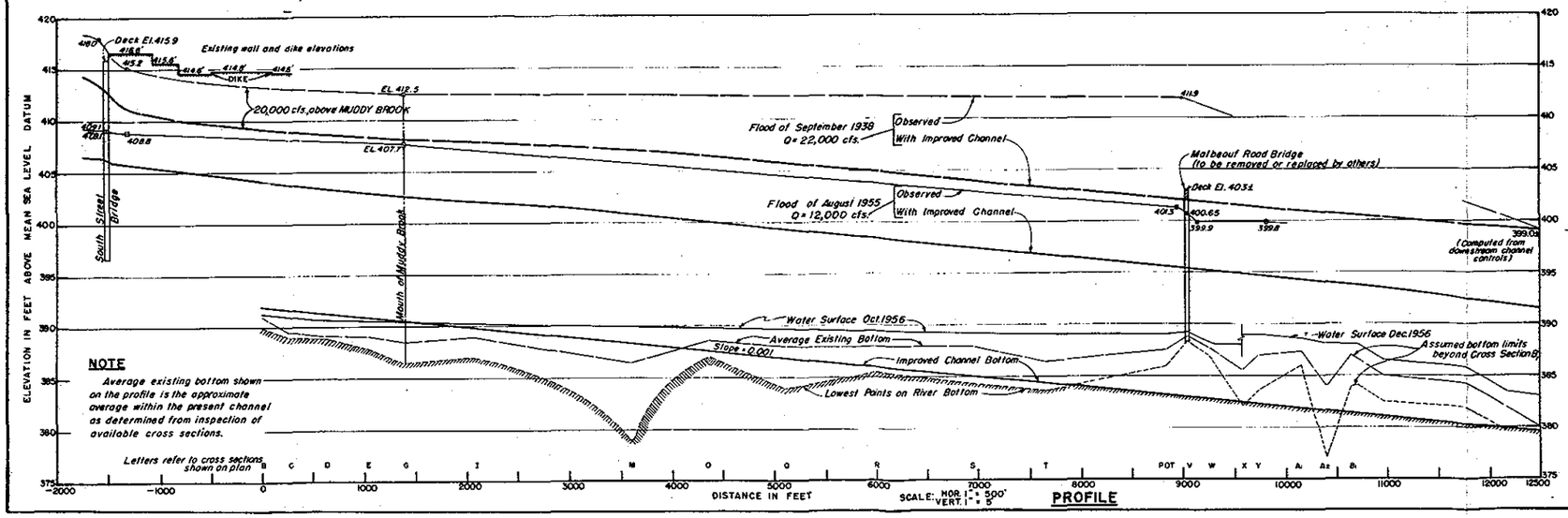
WARE RIVER RATING CURVES

TYPICAL CHANNEL CROSS SECTION

(STA. 51+00)

SCALE 1" = 20'

20' 0 20' 40'



PROFILE

NOTE

Average existing bottom shown on the profile is the approximate average within the present channel as determined from inspection of available cross sections.

NOTES

Elevations refer to Mean Sea Level Datum.

Where improved channel bottom is above elevation of existing channel it refers to excavation for increased width as shown on Typical Channel Cross Section.

Locations of spoil areas will be developed for final plans.

Cross hatched areas indicate approximate areas to be widened.

CORPS OF ENGINEERS U. S. ARMY

CONNECTICUT RIVER FLOOD CONTROL

WARE, MASS.

LOCAL PROTECTION

GENERAL PLAN AND PROFILE

WARE RIVER MASSACHUSETTS

APRIL 1957

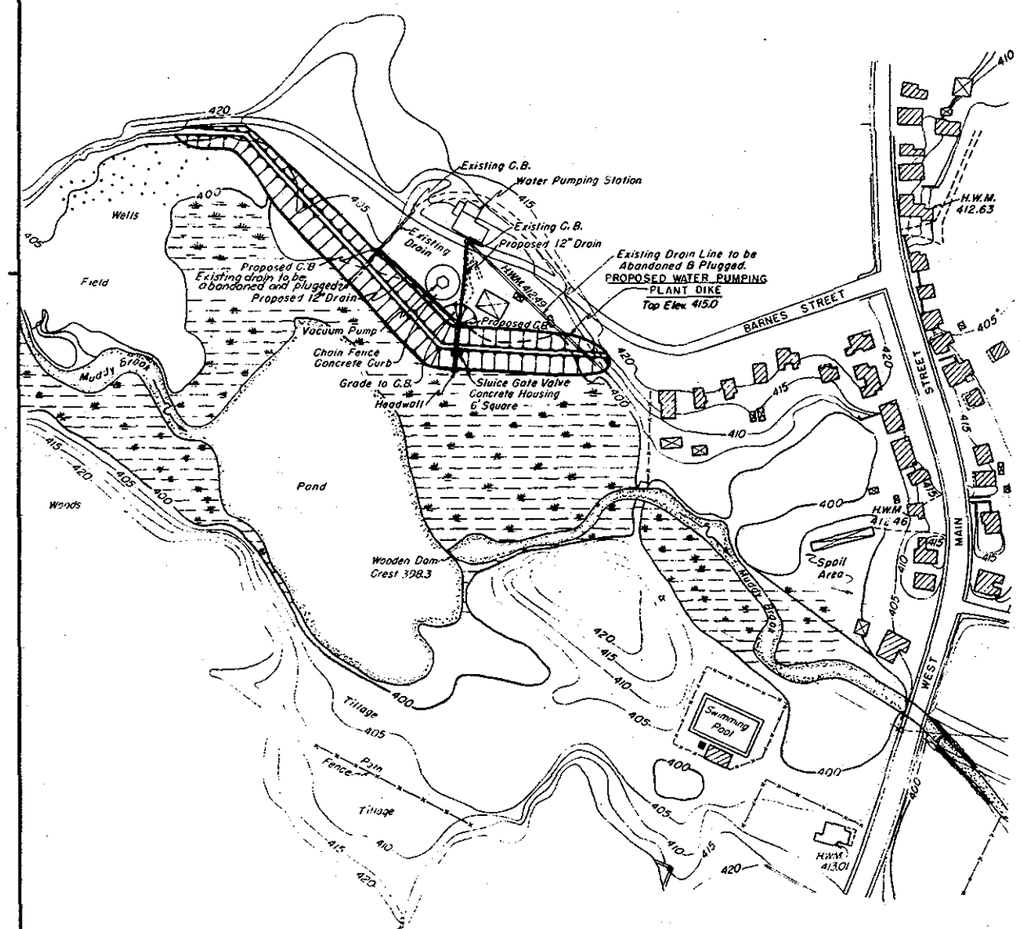
AS SHOWN

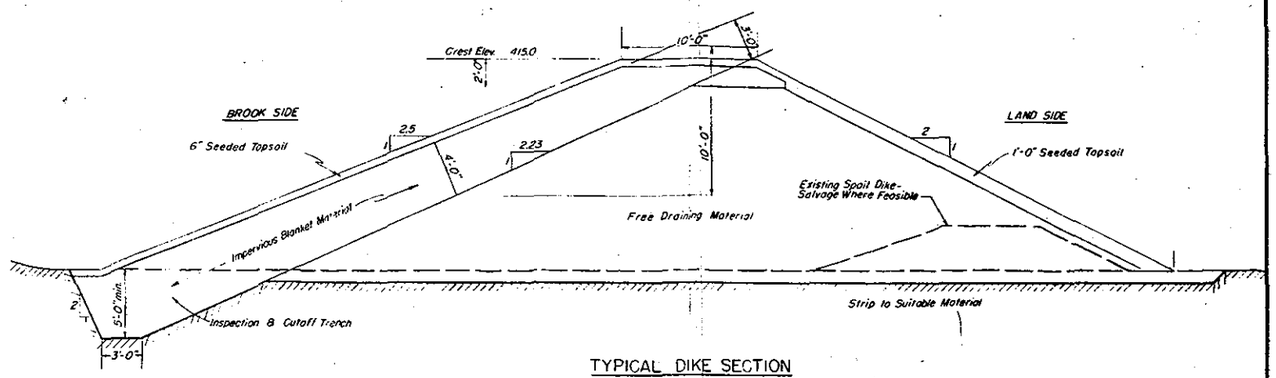
CT-1-4437

PLATE NO. 2

CORPS OF ENGINEERS

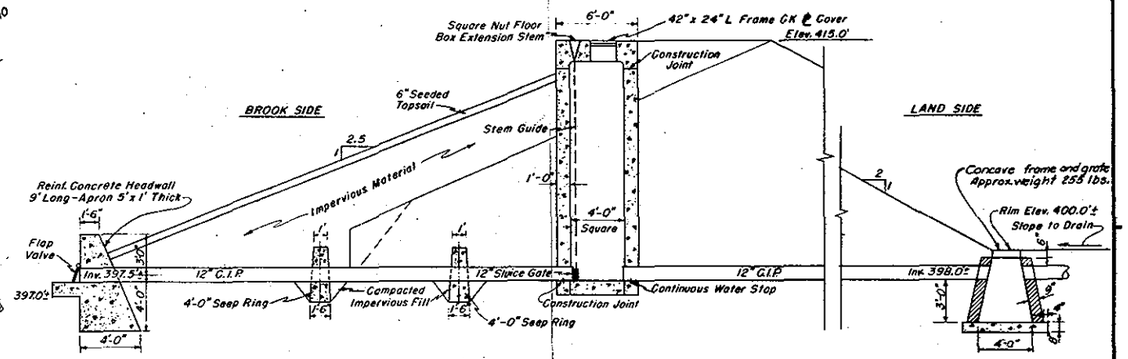
U. S. ARMY





TYPICAL DIKE SECTION

SCALE: 1/4"=1'-0"



DRAINAGE STRUCTURE DETAIL

SCALE: 1/4"=1'-0"

REVISION	DATE	DESCRIPTION	BY

CORPS OF ENGINEERS, U. S. ARMY
OFFICE OF THE DIVISION ENGINEER
NEW ENGLAND DIVISION
BOSTON MASS

DR. BY	TR. BY	CK. BY
R.A.F.	D.M. W.J.C.	J.E.P.

J. W. Hirko
PROJECT ENGINEER

SUBMITTED BY: A.T.S.
CHIEF ENGINEERING DIV.

APPROVED: [signature]
CHIEF ENGINEERING DIV.

CONNECTICUT RIVER FLOOD CONTROL
WARE, MASSACHUSETTS
LOCAL PROTECTION
WATER PUMPING PLANT DIKE
WARE RIVER MASSACHUSETTS

APPROVED: [signature]
LT. COL. C.E. ASST. DIVISION ENGINEER

DATE: APRIL 1957

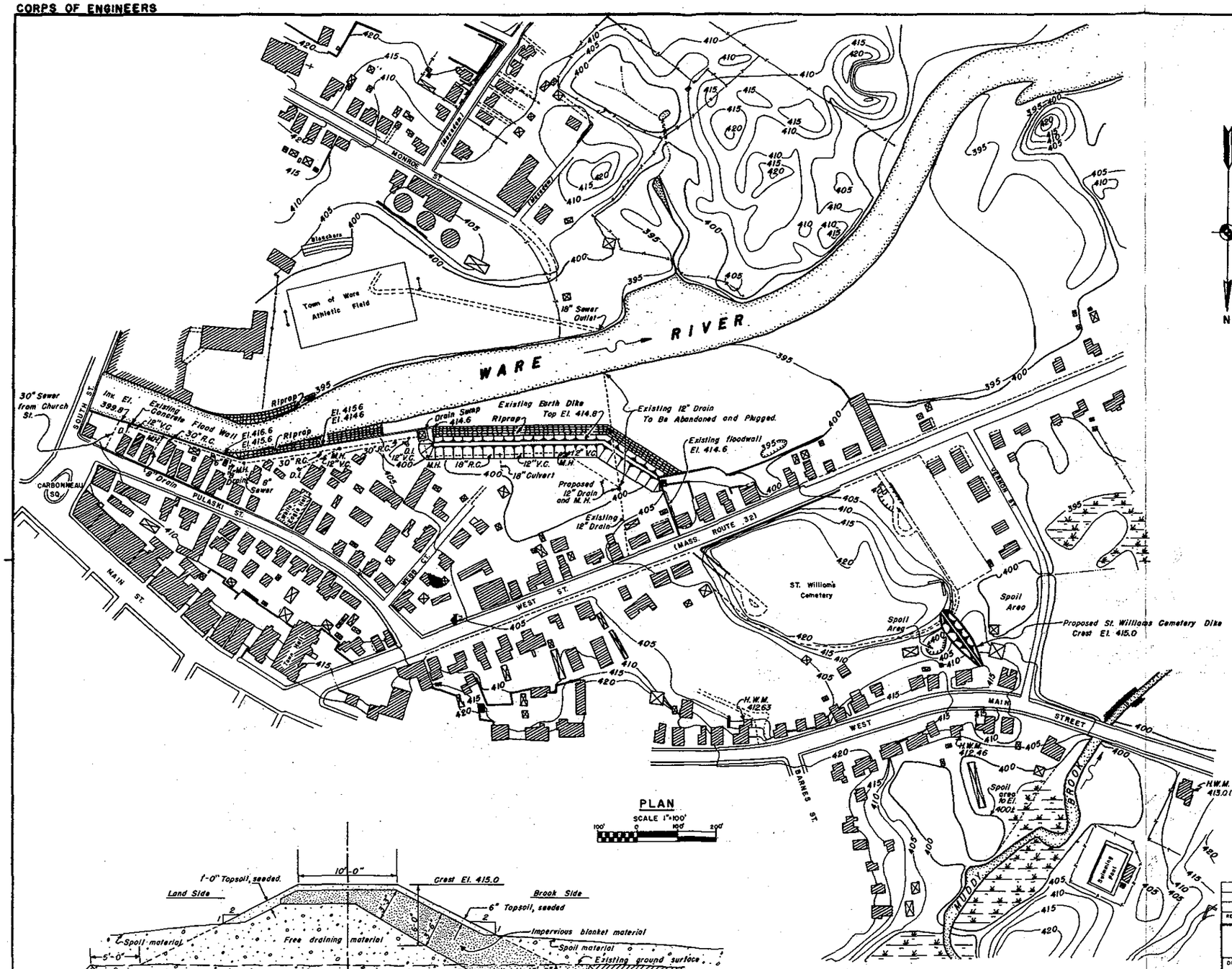
SCALE: AS SHOWN

DRAWING NUMBER
CT-1-4438

SHEET 1 OF 1

PLATE NO. 3

CORPS OF ENGINEERS U.S. ARMY



PLAN

SCALE 1"=100'

TYPICAL DIKE SECTION

SCALE 1"=4'

REVISION	DATE	DESCRIPTION	BY

CORPS OF ENGINEERS, U. S. ARMY
OFFICE OF THE DIVISION ENGINEER
NEW ENGLAND DIVISION
BOSTON MASS

DR BY M.A.F. | TR BY R.G.D. | CK BY J.F.M.

L.W. Kirks
PROJECT ENGINEER

RECOMMENDED BY
CHIEF, ENGINEERING DIV.

APPROVED
LT COL. C.E. ASST. DIVISION ENGINEER

DATE APRIL 1957

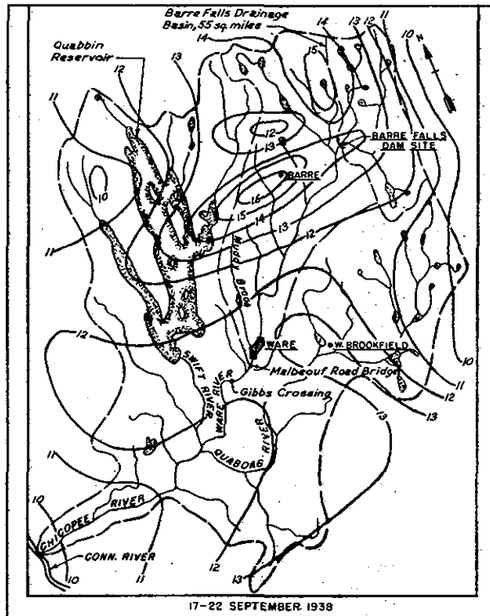
CONNECTICUT RIVER FLOOD CONTROL
WARE MASSACHUSETTS
LOCAL PROTECTION
ST. WILLIAMS CEMETERY DIKE
WARE RIVER, MASSACHUSETTS

SCALE AS SHOWN
DRAWING NUMBER
CT-1-4439
SHEET 1 OF 1

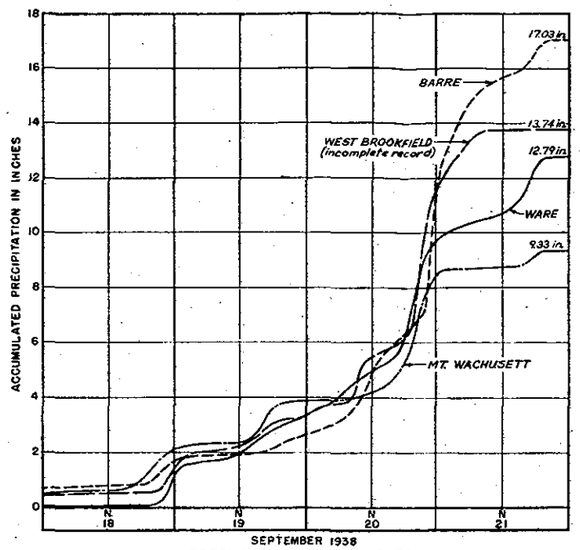
PLATE NO. 4

CORPS OF ENGINEERS

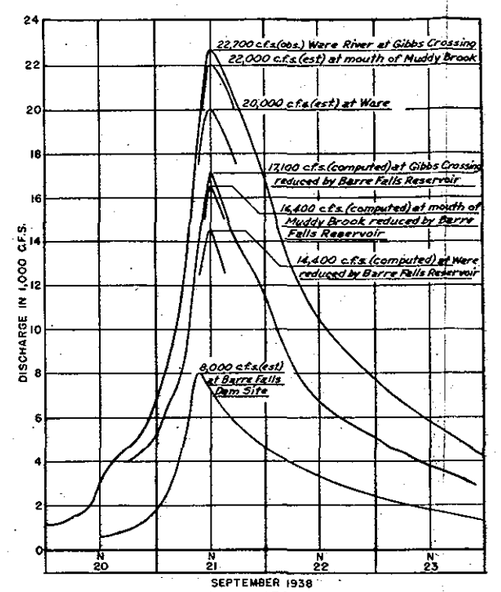
U. S. ARMY



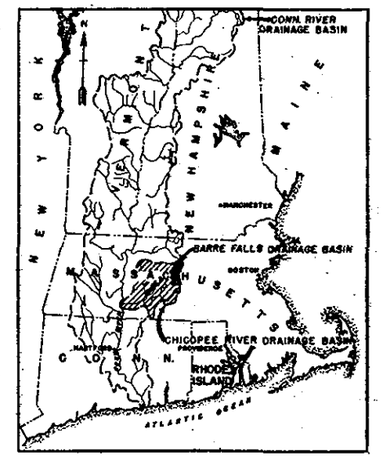
17-22 SEPTEMBER 1938
ISOHYETAL MAP



SEPTEMBER 1938
PRECIPITATION MASS CURVES

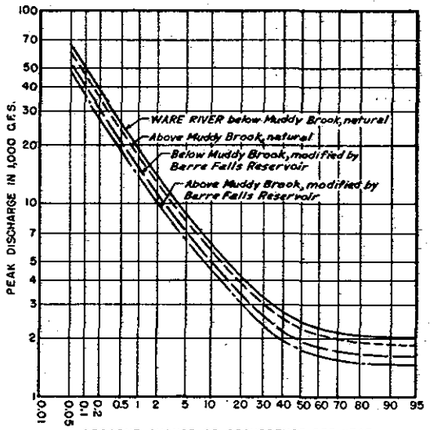


SEPTEMBER 1938
FLOOD HYDROGRAPHS

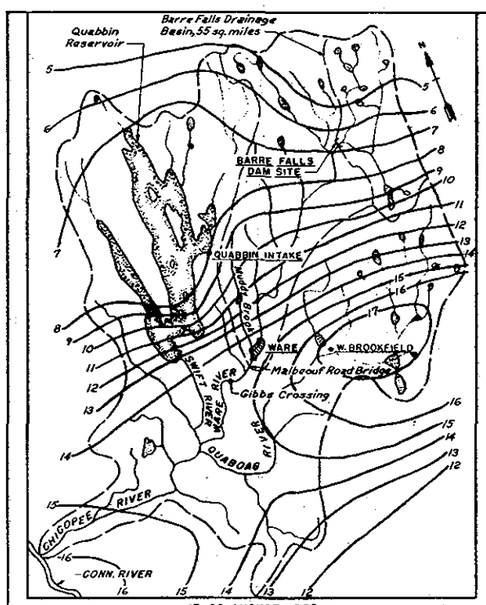


VICINITY MAP
SCALE IN MILES

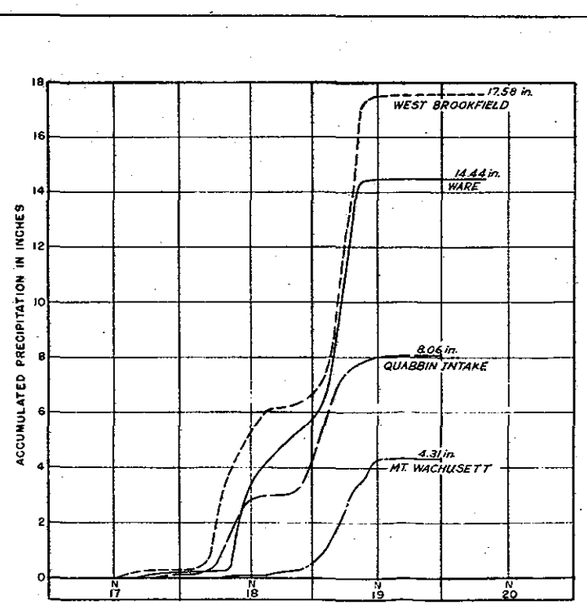
FLOOD OF SEPTEMBER 1938



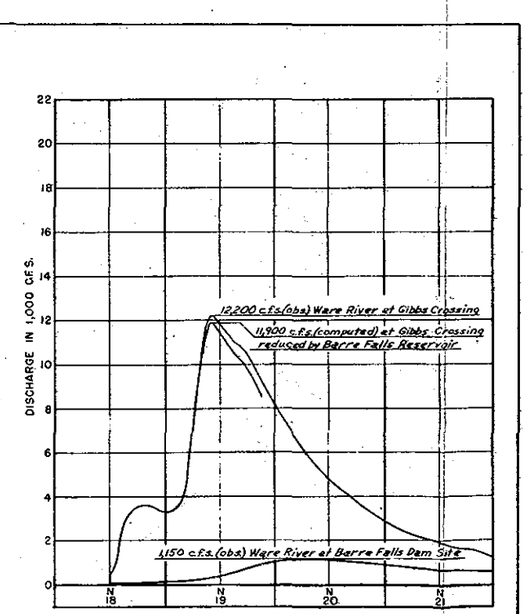
PERCENT CHANCE OF OCCURRENCE PER YEAR
FREQUENCY OF PEAK DISCHARGES



17-20 AUGUST 1955
ISOHYETAL MAP



AUGUST 1955
PRECIPITATION MASS CURVES



AUGUST 1955
FLOOD HYDROGRAPHS

FLOOD OF AUGUST 1955

REVISION	DATE	DESCRIPTION	BY

CORPS OF ENGINEERS, U. S. ARMY
OFFICE OF THE DIVISION ENGINEER
NEW ENGLAND DIVISION
BOSTON, MASS.

DR. BY	TR. BY	CK. BY
M. L.	R. J. C.	

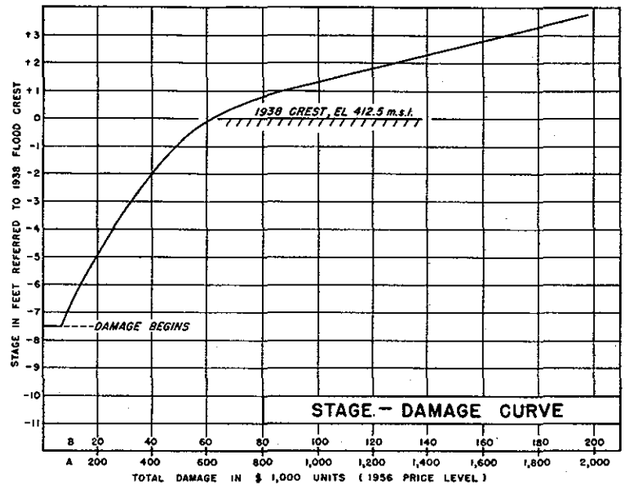
CONN. RIVER & WTR. SECTION
PROJECT ENGINEER
STANDARDS BY
CHIEF, ENGINEERING BRANCH
APPROVED
CHIEF ENGINEERING DIV.

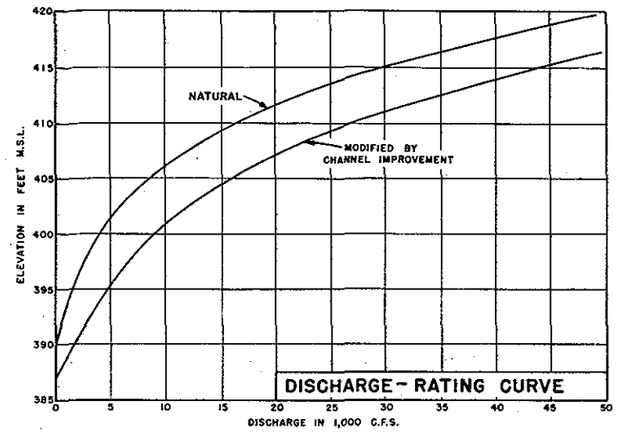
CONNECTICUT RIVER FLOOD CONTROL
WARE, MASSACHUSETTS
LOCAL PROTECTION
HYDROLOGIC STUDIES
WARE RIVER — MASSACHUSETTS

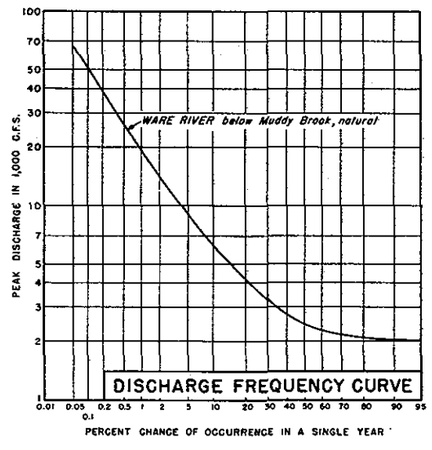
APPROVED
LT. COL. C.E. ASST. DIVISION ENGINEER
DATE APRIL 1957

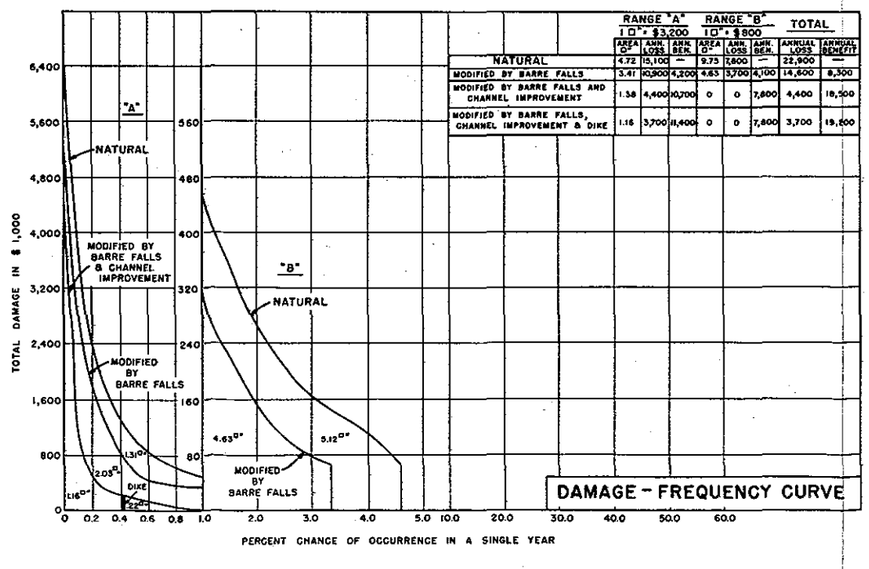
SCALE: AS SHOWN
DRAWING NUMBER
CT-3-1313
SHEET 1 OF 1

PLATE NO. 5









	RANGE "A" D* $3,200			RANGE "B" D* $800			TOTAL	
	AREA D*	ANN. LOSS	ANN. BEN.	AREA D*	ANN. LOSS	ANN. BEN.	ANNUAL LOSS	ANNUAL BENEFIT
NATURAL	4.72	15,100	—	9.73	7,800	—	22,900	—
MODIFIED BY BARRE FALLS	3.41	10,900	4,200	4.83	3,700	4,100	14,600	8,300
MODIFIED BY BARRE FALLS AND CHANNEL IMPROVEMENT	1.38	4,400	10,700	0	0	7,800	4,400	18,500
MODIFIED BY BARRE FALLS, CHANNEL IMPROVEMENT & DIKE	1.16	3,700	11,400	0	0	7,800	3,700	19,200

CONNECTICUT RIVER FLOOD CONTROL

WARE, MASS.

LOCAL PROTECTION PROJECT

TYPICAL CURVES FOR ECONOMIC ANALYSIS

NEW ENGLAND DIVISION — BOSTON, MASS.

APRIL 1957

PLATE NO.6